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Size and survival: An analysis of the university spin-offs

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ABSTRACT

Universities have created USOs to exploit the research knowledge and contribute to the economic development of their regions in the last decades, leading to an extensive literature on the topic. However, this growing literature has widely overlooked the links between firm size and survival. This paper explores simultaneously the role of size and other firm characteristics on the likelihood of the USOs' survival, mainly drawing on the RBV of the firm. The empirical study uses an unbalanced panel consisting of 2,220 observations from 465 Spanish USOs observed between 2005 and 2013 and event (survival) analysis techniques. The results confirm than firm size is positively associated with the USOs' survival. Moreover, the empirical evidence seems to support the existence of a minimum size that, once reached, makes the failure risk of USOs not significantly dependent on size itself. The findings also confirm that the determinants of survival consistently differ between micro USOs and SML USOs. Thus, the survival of micro USOs is negatively affected by those activities that involve high needs of resources, like patent activity or debt payment. In contrast, exporting increases the survival probability of SML USOs.

1. Introduction

Governments, industry and society ask universities to play a more important role in the economic growth of their regions. To achieve this goal, universities use different mechanisms to transfer and commercialise the knowledge and technology developed inside them, including the creation of companies called university spin-offs or USOs (Shane, 2004), firms set up within a higher education institution to put into practice the knowledge generated through the R&D activity of its academics (Miranda et al., 2018) With the rising importance of this kind of firms, recent literature specifically devoted to USOs is flourishing. Nevertheless, the figures show that only 75% of the European USOs survive 6 years after birth (Mustar et al., 2007). Similar results have been evidenced for Spanish USOs (Rodríguez-Gulías et al., 2016; Fernández-López et al., 2020), indicating that 1 out of 4 USOs fails. Moreover, some surviving USOs tend to exhibit very limited activity and growth, falling into the 'living-dead' phenomenon (Mathisen, 2017). The growing importance of these firms, together with the relevance of firms' survival for competitiveness and growth of a country (Giovannetti et al., 2011), requires an assessment of the determinants of the USOs' survival.

The abovementioned failure/survival rates open the debate on the public support for the creation of such firms and, responding to this claim, a handful of studies have analysed this issue. Nevertheless, the number of works remains insufficient to obtain a general empirical assessment of the USOs' survival (Conceiçao and Faria, 2014; Rodríguez-Gulías et al., 2016; Wennberg et al., 2011). Thus, a strand of the literature compares the USOs' likelihood of survival with that of similar firms, yielding inconclusive evidence. Whereas some authors find a higher likelihood of survival for the former (Criaco et al. 2014; Rodríguez-Gulías et al., 2016; Zhang, 2009), the opposite result is obtained by Bonardo et al. (2010), Cantner and Goethner (2011), and Wennberg et al. (2011). A different stream of the literature puts the emphasis on the determinants of the USOs' survival by empirical testing a set of heterogeneous potential drivers of firm survival at firm-level and/or institutional-level (Conceição and Faria, 2014; Fernández-López et al., 2020; Nerkar and Shane, 2003; Prokop et al., 2019; Rodríguez-Gulías et al., 2016; Wennberg et al., 2011) and thereby it limits the generalizability of the results.

Conversely, there is a wide body of research literature examining firm survival/failure. In this domain, firm size is arguably the most studied driver of firm survival (Tsvetkova et al., 2014). Thus, the

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empirical evidence has consistently established a positive association between both variables, either by empirically testing the influential Law of Proportionate Effect (Giovannetti et al., 2011) or other theoretical approaches such as the Penrose's (1959) Theory of the Growth of the Firm. Thus, compared to small firms, large counterparts not only are closer to the minimum efficient scale required to operate efficiently in the market (Audretsch and Mahmood, 1994), but they also have easier access to valuable resources that allow them to develop strong capabilities and, subsequently, sustainable competitive advantages (Barney, 1991). In spite of previous results referred to firms, solid evidence on the links between size and survival remains virtually non-existent in USOs.

The goals of this study are twofold: 1) explore the relationship between size and survival among USOs; and, 2) analyse whether the driving forces of firm survival differ between micro-USOs and small, medium and large (SML) USOs. According to the recommendation of the European ommission (2003), different criteria can be used to classify a firm into micro or SML company. This is not a trivial issue in the case of USOs; mostly knowledge-based firms and often financially-constrained. In this context, firm size measured through the number of employees can act as a proxy for knowledge embedded in the personnel, whereas the total assets or annual turnover might capture the USO's ease of access to financial resources. The rising importance of such firms as well as the huge amount of public funds spent on targeting them require an assessment of their probability of survival. Also, gaining better understanding of USOs' survival is essential for sound policy making. In order to reach these goals, we constructed a sample formed by 2,200 observations from 465 Spanish USOs between 2005 and 2013 (unbalanced panel).

The findings show that firm size measured through employment increases the survival chances of USOs. In detail, the probability of survival is higher in the SML USOs than in the micro USOs, and the difference between both survival probabilities increases as the time passes. In this respect, size plays a more important role in micro USOs than in the SML USOs, suggesting that once a minimum size is reached, size becomes less important for the USOs' survival. Similar, albeit weaker, evidence is shown when firm size is measured by annual turnover. Additionally, the driving forces of the USOs' survival differ between micro and SML firms. Thus, patent activity and indebtedness increase the failure risk of micro USOs, while the opposite effect is found for sales growth. In contrast, the survival chances of SML USOs are positively affected by their export activities.

This paper offers two major contributions. First, it adds to the theory by integrating literature from the firm survival and academic entrepreneurship fields, as well as to the empirical testing of the USOs' survival, which is still limited. Particularly, size has been widely neglected by the literature on USOs in spite of being acknowledged as one of the most important drivers of firm survival (Mata and Portugal, 1994; Tsvetkova et al., 2014). More specifically, this paper analyses how the effect of a set of firms' characteristics is conditioned by the firm size. In so doing, it provides a deeper understanding of how the links between size and the access to valuable resources influence the survival of firms typically resource-constrained such as USOs. Moreover, alternative measures of firm size have been considered in an attempt to reflect the different resource endowments of USOs. In this sense, the results support the idea of the Resource Based View (RBV) of the firm; size facilitates the USOs' access to additional resources, which, in turn, gives occasion for higher survival chances. Second, the obtained results allow us to make some managerial and policy recommendations to improve the survival rates of USOs. Such results and implications might be extrapolated to other similar firms, particularly knowledge-based firms.

This paper is organized as follows. Section 2 introduces the literature and the hypotheses. In Section 3 the methodology is detailed. Section 4 presents the empirical findings. Section 5 discusses the major implications for theory and practice, limitations and future research lines. Finally, in Section 6 the main findings are summarized.

2. Size and survival

Firm survival becomes a more relevant indicator of firm performance for USOs than for other new firms (Criaco et al., 2014). First, the difficulty usually associated with the launch of a new venture are leveraged by the problems related to the innovation development in the former (Berbegal-Mirabent et al., 2015). An early-stage technology, as well as the long-time lag between the research phase and the market launch (Rasmussen and Rice, 2011), put USOs at risk of failure, mainly through the start-up phase (Parmentola and Ferretti, 2018). Moreover, USOs are commonly resource-constrained firms (Zhang, 2009) and lack the resources required to counterbalance the liabilities of smallness (Novotny, 2020; Skute, 2019). They are confronted with the challenge to attain finance to support their growth (Sørheim et al., 2011; Galati et al., 2017) and to gain managerial capabilities which allow them to overcome their lack of prior business (Lundqvist, 2014; Oliveira et al., 2013) and expertise in industry (Drivas et al., 2018). Second, the use of other performance indicators, such as those derived from financial information (namely, firm growth and profitability) have specific problems in USOs. Thus, financial information on technology-based firms gives little data to reach significant conclusions since these companies need important investments in early stages and their market value is often not reflected in financial statements. Besides, sometimes the academics' motivation to create USOs relies on the attempt to continue with the lines of research, rather than on maximizing returns (Migliorini et al., 2010).

Despite the increasing research on the USOs' outcomes (see Hossinger et al. (2020), Mathisen and Rasmussen (2019), Miranda et al. (2018), Skute (2019) or Terán-Pérez et al. (2020) for a recent review of the literature on USOs) there has been little work exploring the USOs' survival (Conceição and Faria, 2014; Rodríguez-Gulías et al., 2016; Wennberg et al., 2011). In fact, a thorough review of the literature produces only a handful of studies that analyse the factors linked to the USOs' survival.

These few studies can be classified into two groups according to Mathisen and Rasmussen (2019): comparative studies between USOs and similar companies (i.e., those ones defined as new technology-based firms), and studies on the determinants of the USOs' survival (Table 1). Within the first group of studies, mixed results are found. Whereas Bonardo et al. (2010), Cantner and Goethner (2011) or Wennberg et al. (2011) find that USOs tend to fail to a greater extent than similar counterparts, the opposite result is observed by Criaco et al. (2014), Rodríguez-Gulías et al. (2016) and Zhang (2009), and no significant relationship is found by Ayoub et al. (2017).

In turn, the second group includes several studies that have explored the firm determinants of the USOs' survival (Conceição and Faria, 2014; Fernández-López et al., 2020; Nerkar and Shane, 2003; Prokop et al., 2019; Rodríguez-Gulías et al. 2016; Rothaermel and Thursby, 2005; Wennberg et al., 2011). In this stream, solid and comparative evidence on the driving forces of the USOs' survival remains virtually non-existent partly because the heterogeneity of the analysed determinants, which are mostly dependent on the research focus of the authors (Ayoub et al., 2017).

Conversely, firm survival is one of the most intensively researched events in the organizational literature (see, for instance, Josefy et al., 2017). Particularly, the literature has extensively analysed the links between size and firm survival (Agarwal and Audretsch, 2001; Dunne and Hughes, 1994; Geroski et al., 2010; Giovannetti et al., 2011; Haveman, 1995; Mata and Portugal, 1994; Mitchell, 1994; Sharma and Kesner, 1996), generally finding a positive association. This correlation is also found for start-ups, firms with similar characteristics to USOs. On their study for electronic product manufacturing start-ups in the US, Tsvetkova et al. (2014) also found a positive correlation between size and survival, helping larger companies to avoid the effect of the 'creative destruction' regime, especially important on highly innovative regional environments. As Geroski et al. (2010) explain, founding effects are

Table 1
Summary of empirical research

Authors	Sample	Comparative studies	Region/ Country	Years	Method	Determinants
Zhang (2009)	704 USOs - 5.655 non USOs	+	USA	1992-2001	Logit model (Survival prob.)	
Bonardo et al. (2009)	131 USOs - 131 non USOs	-	Germany, UK, France and Italy	1995-2003	Cox model (Failure prob.)	
Cantner and Goethner (2011)	128 USOs - 128 non USOs	-	Thuringia (Germany)	2008	Ordinary Least Squares (OLS) (Default risk)	
Criaco et al. (2014)	29 USOs - 63 non USOs	+	Catalonia (Spain)	2011	Mean difference (Mac Nemar test) (Survival: 1; 0)	
Wennberg et al. (2011)*	528 USOs – 8,663CSOs	-	Sweden	1994-2002	Cox Model (Survival prob.)	Entrepreneurial experience Specific human capital (industry experience) Education Characteristics of the spawning parent organization
Rodríguez-Gulías et al. (2016)*	469 USOs - 469 non USOs	+	Spain	2000-2010	Cox Model (Survival prob.)	Size Financial Resources Asset Efficiency
Nerkar and Shane (2003)	128 USOs		MIT (USA)	1980-1996	Waibull Model (Failure prob.)	Industry concentration
Rothaermel and Thursby (2005)	79 USOs		Georgia Institute of Technology (USA)	1998-2003	Multinomial Logistic Regression (Failure; Remaining in incubator; Successful Graduation)	Ties to the sponsoring University
Conceiçao and Faria (2014)	327 USOs		Portugal	1995-2007	Cox Model (Survival prob.)	Size Age Parent reputation Region
Prokop et al. (2019)	870 USOs		UK	2002-2013	Logit model (Survival: 1; 0)	Number of investors External entrepreneurs Technology Transfer Offices (TTO)

Notes: * Although exploring the determinants of the USOs' survival, these works are also comparative studies.

important determinants of exit rates, and, which is even more important, the effect on survival persists for several years. In this sense, size effects are more relevant than others, such as concentration or suboptimal scale (Mata and Portugal, 1994).

Broadly speaking, the underlying arguments for a positive relationship between firm size and survival can be classified into two main groups: the effects of size itself and the role of size in facilitating the access to other valuable resources. Regarding the former effects, the vast literature aimed at empirical testing Gibrat's Law leaded to a promising line of research that evidenced a strong relationship between the likelihood of survival and firm size (Giovannetti et al., 2011). Given that large companies are closer to the minimum efficient scale needed to operate efficiently in the market (Audretsch and Mahmood, 1994), they exhibit a higher likelihood of survival than smaller ones. From the population ecology perspective, this issue is known as the 'liability of smallness' (Audretsch and Mahmood, 1994; Ortega-Argilés and Moreno, 2007) and posits a positive relationship between the 'entry size' and the likelihood of survival of new entrants (Giovannetti et al., 2011). The 'liability of smallness' is also compatible with the theory of strategic niches (Caves and Porter, 1977) that posits that in traditional sectors firms remain small to occupy product niches that are not profitable or easily accessible to large companies. However, in the more technological intensive industries the 'entry size' becomes a relevant competitive advantage (Agarwal and Audretsch, 2001; Giovannetti et al., 2011), increasing the likelihood of firm survival. In the USOs' context, the study of the liability of smallness gains relevance since this kind of firms not only tend to remain small (Ayoub et al., 2017; Harrison and Leitch, 2010; Mustar et al., 2007; Teixeira, 2017) but also, they frequently operate in technological intensive industries (Colombo and Piva 2012). Based on previous literature, the next hypothesis is explored:

Hypothesis: Firm size is positively associated with the USOs' survival

As mentioned, the literature on the determinants of the USOs' survival presents two shortcomings related to the firm size: links between size and survival have been largely overlooked by the existing studies, and when size is considered, it works as a control variable in research designs rather than a key research topic. Thus, Conceiçao and Fariaw (2014) and Fernández-López et al. (2020) find a positive association between firm size and survival, while Rodríguez-Gulías et al. (2016) document an inverted U-shaped relationship, and no significant relationship is found by Prokop et al. (2019). That second shortcoming offers the opportunity to investigate the role played by firm size in the USOs' survival, which brings up the following research question: Are the determinants of the USOs' survival dependent on the USOs' size? Or more specifically, do the driving forces of firm survival differ between micro USOs and SML USOs? In this paper, we aim at answering this question by relying on the second group of arguments for a positive relationship between firm size and survival.

This second group of arguments is grounded within the Resource Based View (RBV) of the firm (Penrose, 1959). This theory maintains that firms' performance lies in its ability to collect and deploy valuable and in-imitable resources in ways that lead to strong capabilities and, consequently, sustainable competitive advantages (Barney, 1991). In this respect, large companies have easier access to financial resources (Fazzari et al, 1988; Geroski et al., 2010), which makes them more resilient to unexpected problems. They are typically more diversified than smaller counterparts, reducing the risk caused by adverse conditions in a single market (Esteve-Pérez and Mañez-Castillejo, 2008; Giovannetti et al., 2011). Large companies also find easier to benefit from better tax conditions (Esteve-Pérez and Mañez-Castillejo, 2008) and from recruiting and retaining high-skilled employees (Geroski et al., 2010), often with a strong educational background in science and engineering, as well as in management (Laursen and Salter, 2004), which become critical disciplines for knowledge-based firms such as USOs. Although the literature on firm survival has largely acknowledged the key role played by the firm's initial resource endowment, the analysis gains additional value if we refer to typically resource-constrained firms such as USOs (Zhang, 2009). Thus, the study of Conceição Faria (2014) indicates that research-based spin-offs with initial (start-up) larger firm size are endowed with superior resources and capabilities, which allow them to increase the firm survival.

Following the Recommendation of European Commission, companies can be classified into different size categories according to the following criteria: number of employees, annual turnover and total balance sheet (European Commission, 2003). However, at the empirical level, a large part of the studies in industrial economics mainly use the criterion based on the number of employees. This has also been the most used criterion by the empirical literature on USOs (see Conceiçao and Faria, 2014; Fernández-López et al., 2020; Prokop et al., 2019).

From the RBV of the firm the use of one criterion or another to measure firm size might indicate different resource endowments. Thus, the number of employees could be a proxy of the USOs' knowledge resource-base. Effective knowledge management allows combining internal and external sources of knowledge enhancing firms' innovation (Andersson et al., 2016), which is a key ingredient for firm success. Particularly, among the internal sources of knowledge, the knowledge embedded in employees becomes a key resource basis of competitive advantage, which let them transform individual and group-level knowledge into products and technologies through the dynamic interaction between tacit and explicit knowledge (Zahra et al., 2007). The high technological knowledge and research experience of the USO's academic founders allow transforming knowledge-based technology into market goods and services (Rothaermel and Thursby, 2005; Colombo and Piva, 2005). Thus, the firm size measured as the number of the USO's employees might positively influence the firm survival since a significant part of knowledge incorporated by USOs and created at universities is tacit an uncodifiable, and the benefits of such knowledge relies on direct interpersonal contact (Criaco et al., 2014; Salvador, 2010; Zhang, 2009). In this respect, Prokop et al. (2019) indicates that the USO's capability to efficiently manage the knowledge of its team determines its competitive position and survival chances.

Concerning the annual turnover and total assets, both measures could act as a proxy of the USOs' access to financial resources. USOs have been often characterised as financially-constrained firms (Mustar et al., 2007). The main financial problem they face is that they receive insufficient external finance, with a lack of larger investments at early stages, due to uncertainty and information asymmetry associated with the technology and core business (Levie and Gimmon, 2008; Widding et al., 2009). While USOs require greater financial efforts in the seed stage, the high levels of uncertainty make them unattractive for private investors, who prefer to invest in USOs that have reached the later stages of development (Wright et al., 2006). Furthermore, USOs often lack tangible assets that may be used as collateral, reducing their chances of obtaining favourable bank loans (Politis, et al., 2012). In these circumstances, a high volume of assets could mitigate information asymmetries and allow USOs greater access to external finance, as they could function as collateral for external capital. At the same time, USOs must resort to internally generated funds, with revenues from their sales being the way to generate these funds.

In sum, previous research has provided evidence that size is positively related to survival rates of firms in general and USOs in particular. The literature has also outlined that firm size can improve survival rates by providing access to other resources, and increasing the already substantial differences between small and large firms. Additionally, the way in which firm size is measured may reflect different resource endowments, being the knowledge embedded in employees and the access to financial resources ones of the most relevant for the USOs' survival. Our purpose is to explore simultaneously the role of size and other firm characteristics on the likelihood of the USOs' survival.

3. Methodology

The following section is devoted to the description of the sample, the variables and the model that have been applied in the analysis of the USOs' propensity to failure.

3.1. The sample

The dataset used in the empirical study was constructed by the fusion of the Red OTRI database, which is composed of 700 USOs established in Spain before 1 January 2011, and the database constructed by Rodeiro-Pazos et al. (2008), which includes 317 USOs established before 1 January 2005[1]. After removing 95 duplicated firms, 922 USOs were in the preliminary unified sample. In next stage, 531 USOs were found in SABI database. Bureau Van Dijk provides this database that was used as main source of information to obtain accounting information and survival data (the firm's legal status, the dates of change in legal status, the dates of last year available and birth dates). In addition, ESPACENET database, supported by European Patent Office (EPO), was employed as source of patent activity data.

Due to the lack of survival and size data some USOs were discarded. Hence, the final dataset was an unbalanced panel consisting of 2,220 observations from 465 Spanish USOs observed between 2005 and 2013.

3.2. Definition and measurements of the variables

Following the extant works on the USOs' survival that used duration models (Bonardo et al., 2010; Conceiçao and Faria, 2014; Fernández-López et al., 2020; Rodríguez-Gulías et al., 2016; Wennberg et al., 2011), the dependent variable was the survival time of the firm in years (_t), that is, the time elapsed between the USO set up date and the moment in which it fails, nuanced by a dummy event variable (_d) that takes the value 1 whether the event (failure) has taken place and 0 otherwise. Hence, the survival time is censored to the right on December 2013 since not for all USOs an exit event occurs over the analysed period (_d=0). Legal status in SABI database was obtained in order to identify failure events. Firms classified as 'bankruptcy', 'state of insolvency', 'extinct', 'dissolved', 'closing of the register', 'provisional closing of the register', 'inactive', 'probably inactive' or 'untraceable according to sources' were considered failed (_d=1). Even the exit event has complex motivations (see Wennberg and Detienne (2014) for a deeper analysis), in this paper we will follow Zhang (2009), pointing that USOs categorized as 'active' or 'merged' were classified as non-failed firms or survivors (_d=0).

Following the recommendation of the European Commission (European Commission, 2003), firm size was measured in three alternative ways based on the number of employees, the annual turnover and total balance sheet. For the three alternative measures, a dummy variable was constructed indicating whether a USO is a SML firm (SML), opposite to be a micro company. Thus, when firm size is measured in terms of employees, the variable SML takes the value 1 when a USO had 10 or more employees. Alternatively, it takes the value 1 when a USO had annual turnover or total assets higher than EUR 2 million. Thus, USOs can change their category from one year to another if the limits are under or overreached. The SML variables will be used in the empirical models estimated over the full sample. Similar to Tsvetkova et al. (2014), these dummy variables will be employed to split the full sample in two subsamples (SML USOs and micro USOs) to answer the research

[1] Red OTRI did not ask universities to identify their USOs prior to 2005. Then, adding this second database allows extending both the analyzed sample and period.

question. In this case, the natural logarithm of the firm's number of employees, total assets and total net sales were also constructed as continuous measures of firm size (LN_SIZE). These continuous variables will be included in empirical models estimated over the subsamples.

Additionally, other explanatory variables common in previous studies on firm survival were included as control variables in order to answer the research question (i.e., whether the determinants of firm survival differ between micro USOs and SML USOs). In particular, we added measures of firm growth, leverage, venture capital funding, technological level, innovation activity and exporting activity. Following Fernández-López et al. (2020), who found that the failure hazard of USOs decreases as firm grows, firm growth has been included. In particular, the firm growth was calculated as the natural logarithm of the quotient of firm's net sales in t divided by net sales in t-1 (G_SALES).

Scholar research seems to support that the survival chances of a USO is influenced by its type of funding, even though few researchers have specifically explored this topic (Ayoub et al., 2017; De Cleyn and Braet, 2009). In this paper, similarly to Bonardo et al. (2010), Rodríguez-Gulías et al. (2016) and Fernández-López et al. (2020), firm leverage was calculated as the leverage ratio (LEV_R), that is, total debt divided by total assets. The previous studies found a positive effect of firm leverage on failure probability of USOs from Germany, the UK, France, and Italy (Bonardo et al., 2010) and Spain (Fernández-López et al., 2020; Rodríguez-Gulías et al., 2016).

Concerning the presence of venture capital (VC) partners, it is expected that it decreases the information asymmetry and the moral hazard through active involvement with the enterprise (Bonardo et al., 2010). Indeed, the literature provides more evidence in favour of hypothesising a positive relationship between attracting VC and the USOs' survival chances (De Cleyn and Braet, 2009). However, prior research yields mixed results. While, De Cleyn and Braet (2009) and Fernández-López et al. (2020) concluded that VC-backed USOs face lower chances of survival, the opposite result is obtained by Bonardo et al. (2010) and Prokop et al. (2019) In this study, a time-invariant dummy (VENT_CAP) that takes the value 1 if the firm had venture capital funding in any of the years of analysis, and 0 otherwise, was used.

Operating in high-tech sectors is arguably riskier than operating in more traditional industries. Against all expectations, previous findings indicate that it has no effect on the USOs' failure propensity (Fernández-López et al., 2020; Rodríguez-Gulías et al., 2016). Here, a USO is defined as a high-tech firm according to the Eurostat classification (Eurostat, 2018) through a dummy variable.

Firm innovation activity has been approximated through patenting. A patent is not only a protection against imitation but also facilitates the access to additional external resources, such as funding and reputation, which, in turn, positively affect its survival (Löfsten, 2016). However, prior research either showed a negative effect (Fernández-López et al., 2020) or no effect (Cantner and Goethner, 2011; Rodríguez-Gulías et al., 2016) of patent activity on the USOs' survival. In this paper, we defined a time-invariant dummy (INNO) that takes the value 1 if the USO had patent activity over the analysis period and 0 otherwise.

Finally, literature on USOs has largely overlooked the relationship between exporting and firm survival (see Table 1). Export activities allow firms to gain efficiency by competing in international markets (Baldwin and Yan, 2011; Du and Temouri, 2011), to sell in markets that grow faster (Del Monte and Papagni, 2003) or simply to compensate for the sales drop in domestic markets (Wagner, 2011). In this sense, Fernández-López et al. (2020) found that the export activities have a significant negative effect on failure hazard of USOs. Here, we defined a time-invariant dummy (EXPORT) that takes the value 1 if the USO had exported over the analysis period and 0 otherwise.

All previous definitions are summarized in Table 2.

Table 2
Definitions of the independent variables

Variable		Measure
Size (based on the number of employees)	SML	1 if the firm had 10 or more employees and 0 otherwise.
	LN_SIZE	Natural logarithm of the firm's number of employees.
Size (based on the total balance sheet)	SML	1 if the firm had total assets higher than EUR 2 million and 0 otherwise.
	LN_SIZE	Natural logarithm of the firm's total assets.
Size (based on the annual turnover)	SML	1 if the firm had annual turnover higher than EUR 2 million and 0 otherwise.
	LN_SIZE	Natural logarithm of the firm's net sales.
Growth	G_SALES	Ln (net sales$_t$ / net sales$_{t-1}$)
Leverage ratio	LEV_R	Total debt in t divided by total assets in t.
Venture capital	VENT_CAP	1 if the firm had venture capital funding in any of the years of analysis, and 0 otherwise.
Industry	HIGH_TECH	1 for firms in medium- and high-tech industries according to the Eurostat classification based on the NACE Rev.2 at the two-digit level and 0 otherwise.
Innovation	INNO	1 if the firm had patent applications filed at the Spanish patent office, the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) or submitted to a Patent Cooperation Treaty in any of the years of analysis and 0 otherwise.
Exporting activity	EXPORT	1 if the firm exported in any of the years of analysis and 0 otherwise.

3.3. Estimation and model specification

To test the proposed hypotheses, event (survival) analysis techniques were used. This methodology is an appropriate approach to analyse the dynamics of firm failure since contemplate 'time to failure' as an integral factor (Chancharat et al., 2007; Kleinbaum and Klein, 2005). The event failure is the consequence of firm strategies over time and should be contemplated as a continuous process although it happens at a specific point of time (Dimitras et al., 1996).

Event models had been chosen based on three issues. Firstly, this methodology allows examining the effect of a set of explanatory variables on the time span before the failure event. Secondly, the explanatory variables can be time-varying covariates, which allows, on one hand, to overcome the limitation of considering uniquely characteristics previous to the time of a firm's entry in the dataset as determinants of its survival probability (Esteve-Pérez and Mañez-Castillejo, 2008) and, on the other hand, to deal with the deterioration in those variables which involves different effects during the firm's failure process (Luoma and Laitinen, 1991). Thirdly, survival models are able to deal with samples where the exit event does not occur during the observation period (right-censored samples).

Following Bonardo et al. (2010), Wennberg et al. (2011), Rodríguez-Gulías et al (2016) and Fernández-López et al. (2020), the Cox proportional hazards model specification (Cox, 1972) is used:

$$h(t|x_j) = h_0(t)\ e^{(\beta_x\ x_j)}$$

where $h_0(t)$ is the baseline hazard, x_j is the vector of explanatory variables and β_x is the vector of their coefficients.

In particular, the basic specification of the proposed Cox proportional hazards model is as follow:

$$h(t|x_j)=h_0(t)\exp(\beta_1 SIZE_{ij}+\beta_2 G\_SALES_{ij}+\beta_3 LEV\_R_{ij}+\beta_4 VENT\_CAP_i +\beta_5 HIGH\_TECH_i+\beta_6 INNO_i+\beta_7 EXPORT_i)$$

where SIZE is measured by the variables SLM_{ij} when the full sample is used and by LN_SIZE_{ij} when the models are estimated over the subsamples (micro USOs and SML USOs).

In this respect, Wennberg et al. (2011) outline two major advantages of the Cox proportional hazards model: any assumption regarding the duration dependence is required and it lets for flexible handling of the non-linear relations and the time-varying covariates.

Concerning the assumption about duration dependence, the Cox model makes no assumptions about the shape of the hazard over time, leaving unestimated the baseline hazard ($h_0(t)$). It is assumed that, whatever the general shape, it is the same for everyone (Cleves et al., 2008), so the effect of a unit of change of the explanatory covariates is a constant parallel shift of the baseline function (proportional-hazards assumption). Hence, although these kinds of semi-parametric models are less efficient than the correct parametric specification, it avoids inconsistent estimates since it does not need to make assumption about the baseline hazard h_0 (t) (Cleves et al., 2008). To test this assumption, the test based on the Schoenfeld residuals has been used (Grambsch and Therneau, 1994; Schoenfeld, 1982).

4. Results

4.1. Non-parametric and descriptive analysis

During the analysed period (2005–2013), 117 out of 465 USOs failed; therefore, the failure rate was 25.16%. Figure 1 shows the non-parametric estimate of the survival function, under the Kaplan-Meier estimate procedure, by our main sub-groups: micro USOs and SML USOs. When the size is measured by the number of employees, the estimated probability of survival is higher in the SML USOs than in the micro USOs, and the difference between both survival probabilities increases as the time passes. The estimate of the survival functions indicates that 25% of the micro USOs do not survive after 7.39 years; while the time beyond which 25% of SML USOs are not expected to survive is 10.51 years (Figure 1.a). Indeed, 97 out of 107 failed USOs were micro firms (in terms of employment) at the time of failure, whereas 20 were SML firms. In contrast, when the subsamples are constructed by depending on total assets (Figure 1.b.) and annual turnover (Figure 1.c), the trends of the survival function is not as clear as in the previous case and sometimes they overlap[2].

a Number of employees
b Total assets
c Total turnover

To test the significance of the difference in the survival functions between the two sub-groups of USOs, we performed a set of homogeneity tests or tests of equality of survivor functions (Table 3). All the tests reject the null hypothesis that the survivor functions of the two groups are the same when size is measured by the number of employees, but not in the remaining two measures of firm size. Hence, we can conclude that the survivor functions of the micro USOs and the SML USOs are significantly different only when subsamples are constructed by considering the number of employees.

Given the previous results (Figure 1 and Table 3), we decided to focus the analysis on the size measured through employment, since it is the only case where significantly different survival functions arise, and to use the other two alternative measures of firm size in the robustness analysis. Thus, Figure 2 depicts smoothed hazard rates for both subgroups. The risk of failure for SML USOs (10 or more employees) is relatively low but keeps increasing until around 8 years after birth and, after a period of reduction (around 2 years), starts increasing again. The smooth hazard function for the micro USOs (less than 10 employees) follows a trend similar to that of the SML USOs, but the failure risk in micro USOs is higher over all ages and increases faster than in SML USOs.

Table 4 shows the descriptive statistics of the explanatory and control variables for both, micro USOs and SML USOs.

The average number of employees is 3.88 people in micro USOs and 23.27 in SML USOs. Firms have an average annual sales growth about 179% in micro USOs and 57% in the larger ones. The mean leverage ratio is about 79.8% and 64.7% in micro and SML USOs, respectively. The percentage of observations of VC- backed micro USOs is 13.2% while 45.5% of them operate in the medium and high-tech industries. In the case of SML USOs, these percentages are higher (33.6% for VC-backed firms and 57.2% for medium-high-tech firms). The percentage of observations with patenting activity is 12.7% in micro and 31.7% in SML USOs, while firms with exporting activity is 12.7% in micro and 40.5% in SML USOs.

Finally, Table 5 displays the correlation matrix of independent continuous variables for both groups of USOs.

4.2. Semiparametric analysis: firm size based on the number of employees

The estimated results of the Cox proportional hazards models for the full sample, the micro USOs and the SML USOs subsamples are reported in Table 6. To test the established hypothesis different empirical models were estimated. Model 1 included the variables: SIZE, G_SALES, LEV_R, VENT_CAP and HIGH_TECH. Variables referring to the innovation activity (INNO) and export activity (EXPORT) were respectively added over the basic model (Model 1) in Model 2 and Model 3. Finally, Model 4 considers all independent variables. For each of the estimated models, a test based on Schoenfeld residuals was performed in order to test the proportional-hazards assumption. In all of them, the null hypothesis is not rejected suggesting that the models are correctly specified.

As can be seen in Table 6, all the variables except the technology level of industry (HIGHTECH) are significant in any of the subsamples. Considering the whole sample, size (SML) is found to be significant, indicating that SML USOs have a higher probability of survival than micro USOs. These findings, together with the smooth hazard functions of both subsamples (Figure 2), confirm the research hypothesis; firm size in terms of employment increases the survival chances of USOs. This finding is consistent with those of Conceiçao and Faria (2014), Rodríguez-Gulías et al. (2016) and Fernández-López et al. (2020). Additionally, after splitting micro from SML USOs, size, measured by the number of employees (LN_SIZE), does not show a significant effect for the SML USOs, whereas it holds significant coeficients in two of the estimated models for micro USOs suggesting that size plays a more important role for the latter than for the former; in other words, micro USOs are more exposed to the liability of smallness than SML USOs. This evidence appears to support the existence of a minimum size after which the failure risk of USOs is not significantly dependent on size itself.

Similar to Tsvetkova et al. (2014), the sample was divided attending to the firm size and the models were re-estimated in order to explore whether the survival determinants differ between micro and SML USO (the research question)[3]. The estimated models indicate that the driving forces of survival strongly differ between micro USOs and SML USOs. Thus, micro USOs performing patent activity (INNO) have lesser survival probability than non-innovative ones. This result is partly consistent with that by Fernández-López et al. (2020) and Nerkar and Shane

[2] For the sake of simplicity, we only considered a single criterion for each alternative size measure. In this respect, only 77 of 1699 observations (4.53%), between firms with less than 10 employees, showed annual turnover and/or annual balance sheet total higher than EUR 2 million.

[3] Additionally, we explored the difference between other size categories. More specifically, given that the vast majority of Spanish companies are micro companies (around 83% in 2020), we performed some tests by splitting the micro category into two categories: micro USOs and super micro USOs (with 2 or less employees). The estimated results of the Cox proportional hazards model when size is measures in this way do not change significantly from results included in the paper. These estimations are not included for space reasons.

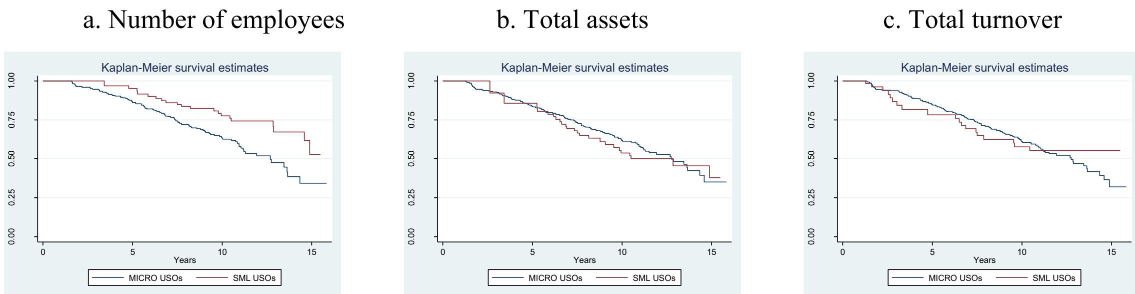

Fig. 1. Kaplan-Meier estimate of the survival function: micro vs. SML USOs

Table 3
Test of equality of survivor functions by sub-groups: micro vs. SML USOs

Test	Number of employees Micro vs. SML USOs		Annual balance sheet Micro vs. SML USOs		Total turnover Micro vs. SML USOs	
	χ^2	*p*-value	χ^2	*p*-value	χ^2	*p*-value
Log-rank	6.10	0.0135	0.33	0.5643	0.00	0.9965
Wilcoxon	3.90	0.0484	1.22	0.2698	0.69	0.4059
Tarone-Ware	4.90	0.0268	0.92	0.3374	0.30	0.5813
Peto-Peto-Prentice	5.47	0.0194	0.64	0.4248	0.21	0.6447

Note: Null hypothesis is that no difference in survivor functions exists.

(2003), who found that the survival probability of the USOs in concentrated industries decreases as the radicalness and the scope of patenting increases. Given that patent activity is a high resource-consuming strategy, this finding appears to indicate that patenting is a riskier activity for the smallest USOs, increasing their risk of failure.

Similarly, an increase in the leverage ratio (LEV_R) of micro USOs increases their failure probability. This result is consistent with the findings of Rodríguez-Gulías et al. (2016) and Fernández-López et al. (2020). Higher share of debt means higher amounts of external financial resources to be spent on building competitive advantages. This availability of financial resources becomes especially relevant for resource-constrained firms such as USOs (Zhang, 2009). Nevertheless, equal leverage ratios imply different amounts of available funds for micro and SML USOs. In the former, it implies not only lesser amounts of external funds, but also lesser internal funding guaranteeing debts and, consequently, a higher risk of default compared to the larger counterparts.

Sales growth (G_SALES) increases the probability of survival in micro USOs. This finding is consistent with the results of Fernández-López et al. (2020). On the contrary, for SML USOs, sales growth does not show a significant effect on survival. As the likelihood of survival is positively related to growth in the smallest USOs, this result seems to refute, somehow, Gibrat's Law.

The export activities (EXPORT) have a positive effect on the survival probability of SML USOs. In the sample considered, the estimates strongly indicate that the exporting SML USOs are less likely to fail than non-exporters. Similar results were obtained by Fernández-López et al. (2020). In this respect, the literature on firm survival has consistently established a positive association between exporting and survival. The arguments behind this relationship mainly refer to the higher efficiency of exporters (Baldwin and Yan, 2011; Du and Temouri, 2011), as well as the opportunity of selling in foreign markets that grow faster (Del Monte and Papagni, 2003) and/or compensating the sales drop in domestic markets caused by negative demand shocks (Wagner, 2011). Nevertheless, because international activities also require an important set of available resources, it seems that only SML USOs can take advantage of

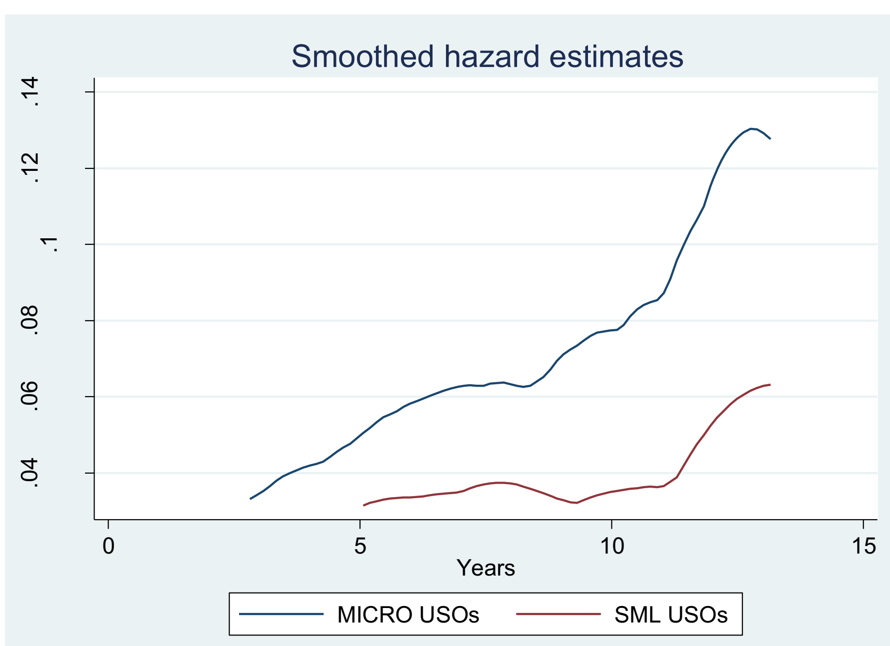

Fig. 2. Smoothed hazard estimates: micro vs. SML USOs

Table 4
Descriptive statistics of independent variables: micro vs. SML USOs

	Variable	Obs.	Mean	Std. Dev.	Min	Max
Micro USOs	EMP[a]	1699	3.877	2.364	1.000	9.000
	G_SALES[a]	1214	1.792	11.842	-0.999	270.013
	LEV_R	1699	0.798	1.022	0.002	22.359
	VENT_CAP	1699	0.132	0.339	0	1
	HIGH_TECH	1699	0.454	0.498	0	1
	INNO	1699	0.164	0.370	0	1
	EXPORT	1699	0.127	0.333	0	1
SML USOs	EMP[a]	521	23.269	24.912	10.000	445.000
	G_SALES[a]	469	0.572	2.144	-0.972	33.714
	LEV_R	521	0.647	0.274	0.100	2.371
	VENT_CAP	521	0.336	0.473	0	1
	HIGH_TECH	521	0.572	0.495	0	1
	INNO	521	0.317	0.466	0	1
	EXPORT	521	0.405	0.491	0	1

Note: [a] Variable is not in logs.

Table 5
Correlation matrix: micro vs. SML USOs

		EMP	G_SALES	LEV_R
Micro USOs	EMP	1		
	G_SALES	0.0091	1	
	LEV_R	-0.0512*	-0.0179	1
SML USOs	EMP	1		
	G_SALES	-0.0095	1	
	LEV_R	-0.0604	0.0114	1

Notes: This table shows the Pearson correlation coefficients for the continuous variables considered in the empirical analysis. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 6
Cox estimation: number of employees as a size measure

	FULL SAMPLE				MICRO USOs			SML USOs		
MODEL	**1**	**2**	**3**	**4**	**2**	**3**	**4**	**2**	**3**	**4**
SML	-0.838**	-0.991***	-0.618*	-0.781**						
	(0.285)	(0.293)	(0.288)	(0.297)						
LNSIZE					-0.324+	-0.199	-0.293+	-0.835	-0.627	-0.688
					(0.173)	(0.171)	(0.174)	(0.513)	(0.509)	(0.509)
G_SALES	-0.361***	-0.365***	-0.348***	-0.350***	-0.305**	-0.292**	-0.299**	-0.321	-0.287	-0.242
	(0.096)	(0.097)	(0.097)	(0.097)	(0.108)	(0.109)	(0.108)	(0.283)	(0.303)	(0.300)
LEV_R	0.126*	0.103*	0.122*	0.101*	0.100+	0.124*	0.097+	1.221	1.066	1.107
	(0.050)	(0.049)	(0.051)	(0.050)	(0.052)	(0.053)	(0.052)	(0.842)	(0.861)	(0.858)
VENT_CAP	0.760**	0.585*	0.948***	0.765**	0.750*	0.964**	0.827*	0.666	1.279*	1.046+
	(0.260)	(0.269)	(0.264)	(0.273)	(0.329)	(0.325)	(0.333)	(0.545)	(0.559)	(0.595)
HIGH_TECH	-0.075	-0.127	-0.122	-0.178	-0.235	-0.238	-0.252	0.767	0.717	0.606
	(0.211)	(0.212)	(0.212)	(0.214)	(0.245)	(0.244)	(0.246)	(0.560)	(0.568)	(0.573)
INNO		0.728**		0.710**	0.841**		0.828**	0.818		0.626
		(0.250)		(0.252)	(0.301)		(0.301)	(0.532)		(0.555)
EXPORT			-1.025**	-0.996**		-0.623	-0.600		-1.397*	-1.281+
			(0.374)	(0.373)		(0.435)	(0.436)		(0.669)	(0.677)
Firm-year obs.	1683	1683	1683	1683	1214	1214	1214	469	469	469
Unique firms	416	416	416	416	369	369	369	131	131	131
Failures	97	97	97	97	79	79	79	18	18	18
Log-likelihood	-464.2	-460.3	-459.6	-455.9	-352.4	-354.6	-351.2	-58.1	-56.6	-55.9
Schoenfeld test*	3.52	5.87	4.61	7.02	9.57	6.42	10.86	1.74	2.98	2.94
p-value	0.6209	0.4379	0.5953	0.4269	0.1441	0.378	0.1449	0.9418	0.8118	0.8903

Notes: SML is a dummy variable that the value 1 when a USO had 10 or more employees, and 0 otherwise. LNSIZE is a continuous variable calculated as the natural logarithm of the firm's number of employees * The null hypothesis is that the hazard rate is proportional. Standard errors in parentheses. $+ p < 0.10$, $* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

the previously mentioned benefits, increasing their survival probability.

Unlike the abovementioned determinants of the USOs' survival, the presence of VC partners (VENT_CAP) increases the failure risk regardless the USOs' size. Moreover, it seems to play a more important (negative) role in the micro USOs. These results differ from those of Bonardo et al. (2010) and Prokop et al. (2019), who find that the number of institutional investors (including venture capital partners) increases the USOs' survival. However, the findings are consistent with those by De Cleyn and Braet (2009) and Fernández-López et al. (2020). This difference could be partly due to how VC was measured in this study (through a time-invariant variable), or simply it would explain the different context surrounding VC in Spain and the UK. In this respect, some VC funds in the context of the Spanish USOs providing, somehow, public-seed funding, which can negatively affect the USOs' performance, as Ayoub et al. (2017) showed for a sample of 524 German USOs that receive public subsidies.

As mentioned, the technology level (HIGH_TECH) of the USOs' industry is the only variable that does not show a significant effect on the failure risk, which confirms the findings of Rodríguez-Gulías et al. (2016) and Fernández-López et al. (2020). However, it is noteworthy that the variable has a negative sign for the sample of micro USOs and the opposite one for the SML USOs. Although not significant, the estimates suggest that operating in high technology sectors increases the survival probability of the smallest USOs, which is contrary to the expected by the theory of the strategic niches.

In sum, the proposed hypothesis has been confirmed, suggesting that USOs with less than 10 employees are more exposed to the liability of smallness than large counterparts. We also answered the research question showing that the determinants of the USOs' survival are largely dependent on firm size. In this respect, the obtained evidence speaks in favour of the arguments stemming from the RBV of the firm. In this line of reasoning, the main contribution of size to increase the USOs' survival is through the access to additional resources that are especially valuable for typically resource-constrained firms such as USOs. In the previous analyses, the size has been measured through the number of employees that can, to some extent, capture the tacit knowledge embedded in the personnel of the USOs. In knowledge-based firms such as USOs, the availability of this resource proves to be crucial to increase the survival chances of the smallest ones.

4.3. *Robustness analysis: firm size based on the annual turnover and total assets*

To check the robustness of the results, we re-estimated the previous models using the other two alternative measures of firm size[4]. The estimated results of the Cox proportional hazards models for the full sample and the subsamples (micro USOs and SML USOs) are displayed in Table 7 and 8.

Concerning the full sample, size (SML) is found to be significant when it is approximated by the total net sales, but this effect does not hold when firm size is based on the total assets. After dividing the full sample in micro and SML USOs, the continuous size variables (LN_SIZE) do not show a significant effect on the survival of the SML USOs, similarly to what happened when firm size was measured through employment. However, a positive relationship is found between the annual turnover and firm survival in the micro USOs.

With regard to driving forces of survival, obtained results generally confirm what was previously found when size was based on the number of employees, with some exceptions. For instance, sales growth (G_SALES) does not show any effect on the probability of survival of micro USOs when size is measured by the total net sales (Table 8). Furthermore, if the size is measured by the total assets (Table 7), the export activities (EXPORT) have a positive effect not only on the survival probability of SML USOs, also on the survival probability of micro USOs.

Finally, Table 9 summarizes the main findings for the variables of interest.

In sum, descriptive and non-parametric analyses allow us to reject the hypothesis that the survivor functions of the micro and SML USOs are the same only when size is based on the number of employees. These findings suggest that the number of employees may be more useful than other criteria for categorising USOs by size, not only for empirical analyses, but also, after seeing the results of parametric analyses, for designing policies that contribute to their survival.

Indeed, based on such parametric analyses, we can conclude that the micro USO's survival is positively related to the number of employees and the sales growth and negatively affected by the presence of venture capital, the patenting activities and the level of leverage. In contrast, only venture capital and export activities seem to influence the survival chances of the SML USOs. In the robustness analyses, these results generally hold regardless the measure of firm sized used.

Finally, from the RBV of the firm, previous results speak in favour of the role played by the knowledge embedded in the employees in the survival of the micro USOs. Also, weak evidence of the positive relationship between survival and the micro USO's ability to generate internal financing has been found.

5. Discussion

This section outlines some managerial and theoretical implications and offers directions for further research.

5.1. *Implications for theory*

After reviewing the growing literature on the USO's performance, it can be concluded that only a handful of studies have analysed the USOs' survival in general and the survival determinants in particular. This scarcity of works claims for more research on the topic.

Besides, firm size can be proxied by different measures. Particularly, the European Commission recommends basing these measures on the number of employees, annual turnover and total balance sheet (European Commission, 2003). In turn, each of these alternative measures may reflect different resource endowments. Whereas the first one can be associated with the knowledge embedded in the employees of the USOs, the other two measures are related to the access to financial resources, either external funding or the USO's capability to generate internal funds. The obtained results speak in favour of using a size measure mainly based on the number of employees in the USOs' case. This result is in line with the argument that the primary conceptualization of survival in new ventures is continuity of operations (Grimes, 2012) whereas other measures may be less meaningful, since early-stage ventures may not yet be realizing sales.

Additionally, the empirical findings indicate that the size influences the USOs' survival by facilitating the access to additional resources. In other words, the findings speak in favour of simultaneously considering size and other firms' characteristics when analysing the determinants of the USOs' survival. Therefore, we recommend following this empirical approach in future research.

The present analysis also makes sense in other kinds of resource-constrained firms such as new knowledge-based firms. Similarly, the promising results are referred to the Spanish USOs, limiting their generalizability to other countries. Future research agenda clearly needs to extend the analysis to other kind of resource-constrained firms and other countries.

5.2. *Implications for practice and policy*

Previous findings offer interesting implications. Firstly, the number of employees is positively associated with the survival chances of micro USOs, suggesting that the role played by tacit research knowledge of academic founders is crucial to increase the survival of the smallest USOs.

Secondly, the micro USOs are putting their survival at risk when patenting, probably because patent activity consumes a higher share of their resources, compared to larger USOs. Then, from a micro-level perspective, micro USOs could perform patent activity if they are enough confident in commercial benefits derived from patents. Otherwise, they should assess other cheaper innovative activities, or even postpone patenting until reach certain size.

Thirdly, findings show that exporting increases the survival probability for the SML USOs regardless how firm size is measured. In other words, the survival of the SML USOs benefits from selling in foreign

[4] The authors thank an anonymous reviewer for this suggestion.

Table 7
Cox estimation: total assets as a size measure

	FULL SAMPLE				**MICRO USOs**			**SML USOs**		
MODEL	**1**	**2**	**3**	**4**	**2**	**3**	**4**	**2**	**3**	**4**
SML	0.093	-0.058	0.369	0.186						
	(0.279)	(0.294)	(0.286)	(0.308)						
LNSIZE					0.086	0.195+	0.129	0.029	0.140	0.077
					(0.110)	(0.107)	(0.113)	(0.237)	(0.221)	(0.237)
G_SALES	-0.332***	-0.338***	-0.310***	-0.314***	-0.350***	-0.327**	-0.336**	-0.355	-0.277	-0.257
	(0.090)	(0.090)	(0.091)	(0.092)	(0.104)	(0.102)	(0.103)	(0.286)	(0.307)	(0.305)
LEV_R	0.143**	0.128**	0.140**	0.125**	0.137*	0.182**	0.145*	1.226	1.185	1.148
	(0.046)	(0.046)	(0.047)	(0.047)	(0.060)	(0.056)	(0.060)	(0.851)	(0.869)	(0.866)
VENT_CAP	0.389	0.299	0.627*	0.544*	0.551+	0.689*	0.619+	0.598	1.099+	0.993
	(0.262)	(0.268)	(0.269)	(0.275)	(0.334)	(0.331)	(0.336)	(0.569)	(0.603)	(0.614)
HIGH_TECH	-0.136	-0.17	-0.204	-0.231	-0.314	-0.3	-0.326	0.699	0.571	0.503
	(0.200)	(0.202)	(0.203)	(0.204)	(0.242)	(0.241)	(0.242)	(0.557)	(0.565)	(0.572)
INNO		0.473+		0.429+	0.638*		0.584+	0.686		0.457
		(0.249)		(0.260)	(0.309)		(0.313)	(0.538)		(0.574)
EXPORT			-1.308***	-1.269***		-0.818+	-0.752+		-1.503*	-1.412*
			(0.371)	(0.369)		(0.438)	(0.437)		(0.665)	(0.674)
Firm-year obs.	1826	1826	1826	1826	1214	1214	1214	469	469	469
Unique firms	434	434	434	434	369.0	369.0	369.0	131.0	131.0	131.0
Failures	107	107	107	107	79	79	79	18	18	18
Log-likelihood	-529.6	-527.9	-521.4	-520.1	-353.8	-353.6	-352.0	-59.6	-57.2	-56.9
Schoenfeld test*	6.28	8.97	6.88	9.68	7.81	5.71	8.28	5.32	4.63	5.55
p-value	0.2797	0.1754	0.3323	0.2077	0.2526	0.4559	0.3089	0.5038	0.5918	0.5936

Notes: SML is a dummy variable that the value 1 when a USO had total assets higher than EUR 2 million and 0 otherwise. LNSIZE is a continuous variable calculated as the natural logarithm of the firm's total assets. * The null hypothesis is that the hazard rate is proportional. Standard errors in parentheses. $+ p < 0.10$, $* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

Table 8
Cox estimation: total net sales as a size measure

	FULL SAMPLE				MICRO **USOs**			**SML USOs**		
MODEL	**1**	**2**	**3**	**4**	**2**	**3**	**4**	**2**	**3**	**4**
SML	-1.070+	-1.175*	-0.683	-0.847						
	(0.593)	(0.596)	(0.603)	(0.605)						
LNSIZE					-0.359***	-0.371***	-0.342***	-0.415+	-0.261	-0.290
					(0.089)	(0.091)	(0.092)	(0.225)	(0.236)	(0.234)
G_SALES	-0.317***	-0.321***	-0.302**	-0.305***	-0.068	-0.039	-0.077	-0.106	-0.141	-0.089
	(0.092)	(0.092)	(0.092)	(0.092)	(0.120)	(0.119)	(0.121)	(0.304)	(0.327)	(0.320)
LEV_R	0.139**	0.123**	0.133**	0.116*	0.084	0.093+	0.083	0.975	0.954	0.944
	(0.046)	(0.046)	(0.047)	(0.047)	(0.054)	(0.055)	(0.054)	(0.870)	(0.879)	(0.880)
VENT_CAP	0.477+	0.323	0.741**	0.574*	0.672*	0.818**	0.707*	0.379	1.086+	0.809
	(0.244)	(0.256)	(0.253)	(0.265)	(0.321)	(0.317)	(0.324)	(0.574)	(0.579)	(0.631)
HIGH_TECH	-0.113	-0.158	-0.14	-0.189	-0.303	-0.276	-0.307	0.59	0.618	0.491
	(0.199)	(0.201)	(0.200)	(0.202)	(0.243)	(0.243)	(0.243)	(0.567)	(0.565)	(0.576)
INNO		0.527*		0.548*	0.532+		0.537+	0.816		0.625
		(0.240)		(0.243)	(0.299)		(0.299)	(0.542)		(0.559)
EXPORT			-1.123**	-1.124**		-0.31	-0.324		-1.310+	-1.183+
			(0.369)	(0.366)		(0.442)	(0.442)		(0.681)	(0.690)
Firm-year obs.	1826	1826	1826	1826	1214	1214	1214	469	469	469
Unique firms	434	434	434	434	369.0	369.0	369.0	131.0	131.0	131.0
Failures	107	107	107	107	79	79	79	18	18	18
Log-likelihood	-527.4	-525.2	-521.5	-519.1	-346.5	-347.7	-346.2	-57.9	-56.8	-56.1
Schoenfeld test*	5.15	7.47	6.82	9.38	7.77	3.99	8.33	1.42	2.26	2.39
p-value	0.3977	0.2795	0.3379	0.2264	0.2556	0.6777	0.3042	0.9647	0.8938	0.9349

Notes: SML is a dummy variable that the value 1 when a USO had annual turnover higher than EUR 2 million and 0 otherwise. LNSIZE is a continuous variable calculated as the natural logarithm of the firm's annual turnover. * The null hypothesis is that the hazard rate is proportional. Standard errors in parentheses. $+ p < 0.10$, $* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

markets. This positive association between survival and export activities also holds for micro USOs when controlling by total assets of the firm.

Fourthly, the obtained results also prevent micro USOs from holding high levels of debt as payment debt obligation can also consume an important part of their day–to-day financial resources. However, the level of leverage seems not to harm firm survival when controlling by the annual turnover, that is, when the USOs' ability to generate internal funds is considered in the models.

From a mezzo-level perspective (i.e., parent universities and Technology Transfer Offices), the findings suggest that USOs should be firstly helped to reach a certain size, especially in terms of employees and sales, in order to increase their survival probability. Thus, USOs should be trained on scaling-up. As sometimes patenting can be expensive or inefficient in some sectors, parent universities and their Technology Transfer Offices must offer advice USOs how to be innovative through alternative ways of patenting. In a next stage, USOs should be trained on how entering and competing in international markets.

5.3. *Limitations and future research*

This research is not exempt from limitations that lead the way to further research. First, the construction of some variables was

Table 9
Summary of findings by measure of firm size

SML	Number of employees Full sample (-)		Total assets Full sample ()		Total turnover Full sample (-)	
	MICRO USOs	SML USOs	MICRO USOs	SML USOs	MICRO USOs	SML USOs
LN_SIZE	(-)	()	()	()	(-)	()
G_SALES	(-)	()	(-)	()	()	()
LEV_R	(+)	()	(+)	()	()	()
VENT_CAP	(+)	(+)	(+)	()	(+)	()
HIGH_TECH	()	()	()	()	()	()
INNO	(+)	()	(+)	()	(+)	()
EXPORT	()	(-)	(-)	(-)	()	(-)

Notes: (+/ - /) denotes positive/negative/not significant effect on the firm's failure.

conditioned by the information contained in the SABI and ESPACENET databases. Regarding SABI database, time-invariant dummy variables had to be used to measure whether the USOs have export activities and VC partners. Future research could benefit from having continuous variables (for instance, export intensity or the share of funds provided by venture capitalist) to measure both aspects. Additionally, the public or private nature of the VC partners would help in understanding the theoretically counterintuitive result found for the presence of VC ant the USOs' survival chances. Concerning information extracted from ESPACENET, patent activity was also measured by a time-invariant dummy variable. In future investigations it might be possible to use not only a continuous variable for capturing patent activities, but also additional variables in order to consider other types of innovation activities (e.g., product, process, organizational or commercial innovation). Moreover, the use of different variables to measure firm size is a somewhat crude attempt to capture different firm resource endowments. Further research could benefit from surveying USOs to explicitly ask them about the availability of financial and knowledge resources, as well as additional resources such as managerial skills, or access to external sources of knowledge.

Despite the importance of the obtained results on the determinants of the USOs' survival, they are referred to a firm-level. However, there are still many unanswered questions about the role played by the context in increasing the USOs' survival. Further work is required to analyse how the support of the parent universities (mezzo-level) and the entrepreneurship ecosystems (macro level) may influence the USOs' survival.

Finally, socio-economic and institutional situation in Spain can limit the generalization of results to different countries. In this sense, new research focusing on national comparatives can help to generalise these conclusions and build the theoretical background of the topic.

6. Conclusions

In the last decades USOs have been created by universities to exploit the research knowledge and contribute to the economic development of their regions. The increasing interest and efforts on promoting these firm fuelled the debate about the USOs' performance. Responding to this claim, academics and literature have paid attention to the study of the USOs' growth, overlooking such a key outcome as survival/failure. In contrast, a stream of the organizational literature has extensively researched firm survival, establishing a strong relationship between size and survival.

In this paper, we deeply analyse such association in USOs. More specifically, we examine not only the effect of different measures of size on the USOs' survival, but also whether the determinants of survival differ between micro USOs and SML USOs. In so doing, this study provides a better understanding of how the linkages between size and other firms' characteristics may affect the USOs' probability to survive.

The results show that USOs with less than 10 employees have a lesser probability of survival than their larger counterparts. Moreover, the empirical evidence seems to support the existence of a minimum size that, once reached, makes the failure risk of USOs not significantly dependent on size itself. The findings also confirm that the determinants of survival consistently differ between micro USOs and SML USOs. Thus, the survival of micro USOs is negatively affected by those activities that involve high needs of resources, like patent activity or debt payment. For the smallest USOs these activities are riskier than for the larger ones. In contrast, exporting increases the survival probability of SML USOs, whose higher resource–base, compared to micro USOs, allows them to exploit the benefits that literature often acknowledges to selling in foreign markets.

In summary, two important theoretical contributions are made to construct the actual framework of this topic. First, it is relevant to notice that size loses importance as key factor once an efficient minimum size is reached, which implies that policies aimed at enhancing the USOs' survival should differentiate firms by size. Second, it has been shown from previous findings that the main contribution of size to increase the USOs' survival is through the access to additional resources that are especially valuable for typically resource-constrained firms such as USOs, supporting the arguments of the RBV of the firm. Moreover, the findings suggest that tacit research knowledge of academic founders is a key ingredient to increase the survival of the smallest USOs, as well as, albeit to a lesser extent, the capability to generate internal funds. The fact that the survival drivers differ between small and large firms involves that future research should separately analyse the effects of the survival determinants for USOs of different sizes.

CRediT authorship contribution statement

David Rodeiro-Pazos: Conceptualization, Data curtion, Formal analysis, Writing – original draft, Visualization, Supervision, Validation, Writing – review & editing, Project administration. **Sara Fernández-López:** Conceptualization, Methodology, Writing – original draft, Supervision, Writing – review & editing, Formal analysis. **María Jesús Rodríguez-Gulías:** Methodology, Software, Data curtion, Writing – review & editing, Writing – original draft, Formal analysis. **Adrián Dios-Vicente:** Writing – original draft, Formal analysis, Visualization, Writing – review & editing.

Supplementary materials

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